Status Report of Vegetation Community Monitoring at Scotts Bluff National Monument and Agate Fossil Beds National Monument

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EXECUTIVE SUMMARY

The Heartland I&M Network and Prairie Cluster Prototype Monitoring Program - HTLN (formerly the Prairie Cluster Prototype Long-Term Ecological Monitoring Program) has been monitoring at Scotts Bluff National Monument (SCBL) and Agate Fossil Beds National Monument (AGFO) since 1997. During the growing seasons of 1997 to 2004, a total of 24 sites were surveyed for plant community composition at AGFO and SCBL. At AGFO, the 11 HTLN sample sites are primarily composed of three plant community types, prairie sandreed – sand bluestem, needle-and-thread grass – blue grama – threadleaf sedge, and little bluestem – blue grama – threadleaf sedge. At SCBL, HTLN mixed-grass prairie sample sites are composed primarily of the needle-and-thread grass – blue grama – threadleaf sedge community. SCBL sample areas also include a Ponderosa pine woodland and a restoration area. Sampling of the prairie restoration area includes sampling two sites in the adjacent prairie known as the Saddlerock Unit.

During the period of HTLN vegetation monitoring at AGFO and SCBL, a multiple year drought has occurred in western Nebraska. Plant communities have been affected in general, with both SCBL and AGFO having a widespread decrease in both the number and foliar cover of species. Management units across both parks have seen a 50-70% reduction in total foliar cover at each sample site compared to earlier non-drought years. Native species dominate the community composition in all management units except the SCBL restoration area; however, the average number of species found per sample site has declined by nearly 35% since 1999.

Management efforts in the South Bluff unit at SCBL also seem to be affected by the drought. It appears that the prescribed fire in 1998, in conjunction with above-average precipitation for that year, resulted in a short-term decrease in annual exotic brome grass coupled with an increase in total foliar cover and species richness. However, these trends seem to be overwhelmed by the effects of the drought in later years. Persistent drought conditions have decreased the dominance of native species, particularly needle-and-thread grass (*Stipa comata*), which has declined in frequency by nearly 20% since 1999. The declining abundance of native species may be favoring the establishment of exotic brome grass which has increased in frequency by 30% over the same period.

Management efforts in the restoration area at SCBL were initially successful in establishing native species. The foliar cover of seeded grass species was estimated at 25 to 30% in 1998 and 1999. In subsequent years the unit has become increasingly dominated by exotic species whose foliar cover was estimated at 20% in 2004. The foliar cover of seeded grasses was approximately 7% in 2004. One dominant species of the adjacent prairie, the threadleaf sedge (*Carex filifolia*), is completely absent from the restoration sample sites. The restoration unit was treated in May of 2002 with prescribed fire with little noticeable effect. Sustained effort may be required to move the restoration towards a model species composition and structure.

In 2004, HTLN staff collaborated with Dr. Amy Symstad (USGS, Northern Prairie Wildlife Research Center) to investigate the differences between grazed and ungrazed prairie. Data collected by the HTLN at SCBL was compared to data collected outside the monument in grazed prairies. Dr. Symstad's preliminary results suggest few differences between grazed and ungrazed sites except for the greater presence of grama

grass in the grazed sites. Dr. Symstad's report is available at:
http://www1.nature.nps.gov/im/units/ngpn/Pages/monitoring.htm

1.0 INTRODUCTION

1.1 Background

North American prairie once extended across the mid-continent region from Canada to Texas and from the Rocky Mountains to the Appalachian forest. The vast landscape was nearly continuous grassland, transitioning gradually from shortgrass steppe in the west to tallgrass prairie and savanna in the east. These grasslands have figured prominently in our North American heritage.

During the last century, large portions of grassland landscapes were plowed for cropland or converted to livestock pasture. Today, Great Plains grasslands are fundamentally altered by the conversion of prairie to cropland and pasture, the removal or disappearance of native ungulates, drainage of wetlands, and an increase in woody vegetation through plantings and fire suppression. Scientists estimate the loss of native prairie ranges from 80 to 99.9%, with the greatest losses occurring in the tallgrass prairie and oak savanna communities. Further, only 71% of shortgrass prairie and 59% of mixed-grass prairie remain (Knopf and Samson 1997). Fragmentation and isolation continues today at an alarming rate. Additionally, ecological driving forces such as fire and the presence of native faunal species including bison (*Bos bison*), elk (*Cervus elaphus*), and wolves (*Canis lupus*), remain largely absent from prairie systems, having been eliminated or placed under human control; only the plants remain as a reasonable legacy of this past system.

Grassland ecosystems are maintained by a complex disturbance regime including frequent large- and small-scale disturbances. The interactive effect of periodic fire and ungulate grazing is widely recognized as a critical component of the natural disturbance regime in tallgrass prairie ecosystems (Bragg 1995, Davison and Kindscher 1999, Howe 1999, Collins 2000). These in turn, interact with interannual climate variation to affect spatial and temporal dynamics (Collins 1987, Knapp and Seastedt 1998, Knapp *et al.* 1999, Collins 2000). Due to the complex disturbance regimes, grassland systems consist of dynamic mosaics of vegetation patches scattered across the landscape, highly variable in both space and time (Collins and Glenn 1991, Collins and Glenn 1997, Collins 2000, Fuhlendorf and Engle 2001).

Prairies are dominated by a few matrix-forming grass species that effectively control community structure. A large number of less abundant species, referred to as satellite species, contribute to the diversity of prairie systems (Collins 1987, Collins and Glenn 1988, Collins and Glenn 1990). Distribution patterns of satellite species are inherently bimodal, varying within and between growing seasons (Collins and Glenn 1988, Collins and Gibson 1990). The nature of the above-ground plant community (e.g., the diversity of species and functional guilds) plays an important role in determining the stability or resistance to disturbance of a prairie system (Wardle *et al.* 2000).

As fragmentation of the landscape increases, so does the likelihood of invasion by exotic plant species into prairie habitat. Exotic species can influence ecological processes including interspecific competition, primary and secondary succession, nutrient cycling, and ecosystem productivity, diversity, and stability (Bratton 1982). In large, intact ecosystems, reintroduction of historic disturbance regimes, such as frequent fires, can impart resistance to invasions by exotic species. However, fragmented prairie landscapes characterized by small, isolated plant and animal populations are at an increased risk of species loss through local extirpation and are susceptible to exotic species invasion and a corresponding decrease in native diversity (Smith and Knapp 2001). This is coupled with a decreased likelihood of re-colonization of native species from the surrounding landscape (Risser 1996).

Understanding the interactive effects of landscape scale, prairie size, community stability, and community invasibility on prairie health is integral to the preservation and protection of public lands, and in determining the appropriate management strategies to employ. Prairie communities exhibit high year-to-year fluctuations in species composition and abundance; however, in stable systems, the community structure remains constant over long time frames or large spatial scales (Collins 2000, Earnest and Brown 2001). Long-term studies of plant communities and individual species are needed to determine appropriate temporal and spatial scales at which plant communities can be considered stable (Collins 2000).

Long-term ecological monitoring, while contributing to our empirical understanding of prairie communities, is integral to the proper management and protection of the lands entrusted to the National Park Service (NPS). Resource managers of the parks require an effective plant community monitoring protocol to assess their management strategies in maintaining and/or restoring prairie plant community composition, structure, and diversity. Our monitoring strategy attempts to balance the immediate needs of managers for current information and the need for insight into the changes occurring in vegetation communities over time.

1.2 Objectives

Plant community monitoring at SCBL and AGFO is designed to detect and describe changes in prairie and woodland communities. There are four primary objectives for the monitoring:

1. Describe the species composition, structure, and diversity of prairie and woodland communities;
2. Determine temporal changes in the species composition, structure, and diversity of prairie and woodland communities;
3. Estimate the rate of temporal change for species richness and Shannon diversity, specifically as related to management efforts in restoration of prairie habitats.
4. Determine the relationship between temporal and spatial changes and environmental variables including specific management practices.

2.0 METHODS

2.1 Sample Design

A long-term monitoring program must address the problems associated with sampling numerous parameters through space and time while determining an efficient and effective sampling design. Numerous sampling methods have been used to describe prairie community dynamics (Weaver 1954, Kucera and Koelling 1964, Owensby *et al.*

1973, Becker and Crockett 1973, Glenn and Collins 1990). Because of the similarities in the communities being sampled and the scale and scope of monitoring questions, the HTLN vegetation community monitoring protocol is based on the National Science Foundation's Konza Prairie Long-Term Ecological Research Program. For the HTLN, the primary sample unit consists of two permanent, parallel 50m transects with five sets of nested plots systematically spaced along each transect (Figure 1). The variable scale plot design is effective for assessing changes in frequency when sampling multiple species simultaneously. Plot size determines frequency values and frequency values between 30% and 70% allow the greatest potential for detecting increases or declines in species frequency (Elzinga *et al.* 1998). The $0.01m^2$ and $0.1m^2$ plots are useful for detecting changes in frequency of dominant prairie grasses and some ubiquitous forb species. The $1.0m^2$ and $10m^2$ circular plots provide useful frequency estimates for satellite or less common grasses and forbs, and capture more species producing better estimates of species richness and diversity.

The transect pair is the primary sample unit, and is referred to as the sample site. The plot is the secondary sample unit. The plots are used to collect data from the ground flora. Working from the smallest to the largest plot, all herbaceous and woody shrub species are identified. Foliar cover serves as the estimate of abundance for herbaceous and multi-stemmed shrub species. Foliar cover is defined as the area occupied by the perpendicular projection of the aerial parts of individuals of the plant species under consideration to the ground (Greig-Smith 1983). Use of cover estimates are essential for grasses where individuals of a species can rarely be identified and counted. Estimation done by eye is subject to problems of observer-bias. Foliar cover is estimated in the $10m^2$ plot using a modified Daubenmire scale (1959, Table 1). Using cover classes reduces the problem of observer-bias through partitioning all possible values into seven classes with broader cover classes at the upper end of the scale and narrower cover classes at the lower end of the scale.

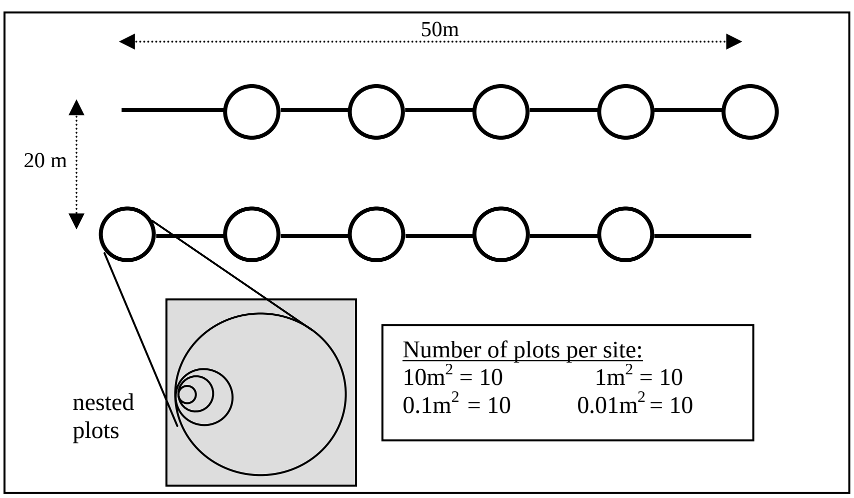


Figure 1 HTLN primary sample unit (i.e., the sample site) comprised of two, 50m long transects with ten sets of nested plots systematically arranged for sampling the ground flora.

Table 1 Modified Daubenmire cover value scale.

Cover Class Codes	Range of Cover (%)
7	95-100
6	75-95
5	50-75
4	25-50
3	5-25
2	1-5
1	0-0.99

The $10m^2$ plots are also used to collect tree regeneration data. Tree species less than 5.0cm diameter at breast height (dbh) are tallied by species in size classes. For analysis, the site is used as the unit of replication and secondary sample units are pooled or averaged. The 0.1ha area between the two transects is used to collect data on the woody species greater than 5.0cm dbh in the understory and overstory canopy layers. Diameter at breast height (dbh) is measured for each individual.

2.2 Site Selection

In order to effectively use limited monitoring resources, information derived from a relatively small number of sample sites must be used to infer changes over a much larger area. For the inference to be valid, a probability based sample design within a defined reference frame is required.

The many different vegetation types, management practices, and park specific data needs, as well as the logistical constraints related to field work, prohibit comprehensive sampling at each park. This prevents simply treating the park as the study unit. In choosing smaller subsets of the park as study units, park-specific resource management issues and/or the desire to capture landscape and community heterogeneity guide the selection. The study unit is the reference frame for which statistical inference is made. In general, study units that represent a range of community types (prairie, savanna, woodland, and glade), conditions (high-quality remnants, restored areas), management strategies, and/or harbor rare species are selected. Where possible the reference frame is park-wide; however, in most small cultural parks it is not desirable to make park-wide inferences since many contain large artificial areas such as lawns, fescue fields and agricultural display fields.

Both SCBL and AGFO are divided into a few large, heterogeneous units generally based on geography. In this case, a study unit that captures the park-wide heterogeneity is selected. Within the study unit, sample sites are located using a stratified random design with soil type and slope position as strata. If multiple units are suitable, then the study unit is chosen at random from the pool. For example, the South Bluff study unit at SCBL contains similar soils, topographic gradients, and vegetation types as other units in the monument (Figure 2). Again, statistical inference is limited to the study unit, but a weight of evidence approach may be judiciously applied to the park as a whole. For example, detection of an increase in exotic, annual grasses in the South Bluff unit may indicate that other management units in the park with similar soils, vegetation, and under similar management are also experiencing an increase in exotic, annual grasses.

There are two main areas of focus at SCBL, the South Bluff Unit and the prairie restoration area. The South Bluff Unit contains both a grassland and woodland component. Sampling of the prairie restoration area also includes sampling two sites outside the restoration known as the Saddlerock Unit. These Saddlerock unit sites are intended to be used for comparisons of restoration success and do not characterize the unit as a whole.

2.3 Data Analysis

From the data collected in each sample site, summary variables are calculated. Summary variables include: (1) plant species richness and diversity, (2) the ratio of exotic to native species, (3) species relative abundance and frequency, (4) prairie plant guild relative abundance, and (5) woody species density and basal area. Changes in these summary variables are used to detect trends over time in the vegetation community.

The plant community variables and indices selected for data summary purposes are complete and descriptive and were designed to provide resource managers with easily interpretable and timely feedback to assist in assessing management practices (Pickett *et al.* 1992). For analysis, the site (i.e. the primary sample unit) is used as the unit of replication and secondary sample units are pooled or averaged. Once estimates for all parameters have been obtained for each sample unit, averages and standard deviation among sample sites can then be obtained for individual study units (management units, reference frames) or for park-wide inference.

Individual Species Abundances and Frequencies

Individual species frequency and percent foliar cover are calculated for each sample unit. Frequency is defined as the number of times a species is present in a given number of plots of a particular size (Raunkiaer 1934). With the sample unit (the paired transects), as the replicate, we report species frequency as the proportion (or percentage) of plots in which the species occurs within each sample unit.

Foliar cover serves as our estimate of abundance for herbaceous species. The cover class intervals are converted to median values to estimate percent cover for each herbaceous and shrub species. Individual species mean percent cover is calculated as the species percent cover for a sampling unit, averaged for all plots in which the species occurs (i.e., plots within a sampling unit with zero values for a species are excluded).

From these basic estimates of foliar cover and frequency are generated the following metrics for each sample unit: (1) species relative cover, (2) species relative frequency, and (3) species importance value. Relative frequency and relative cover are calculated as the frequency and percent foliar cover of species (*i*) on site X, divided by the total frequency and total foliar cover of all species for plot X, respectively.

Species importance value (IV) is an index derived from relative cover and relative frequency, [*relative cover + relative frequency)/2*)]. The importance value gives an overall estimate of the influence or importance of a plant species in the community.

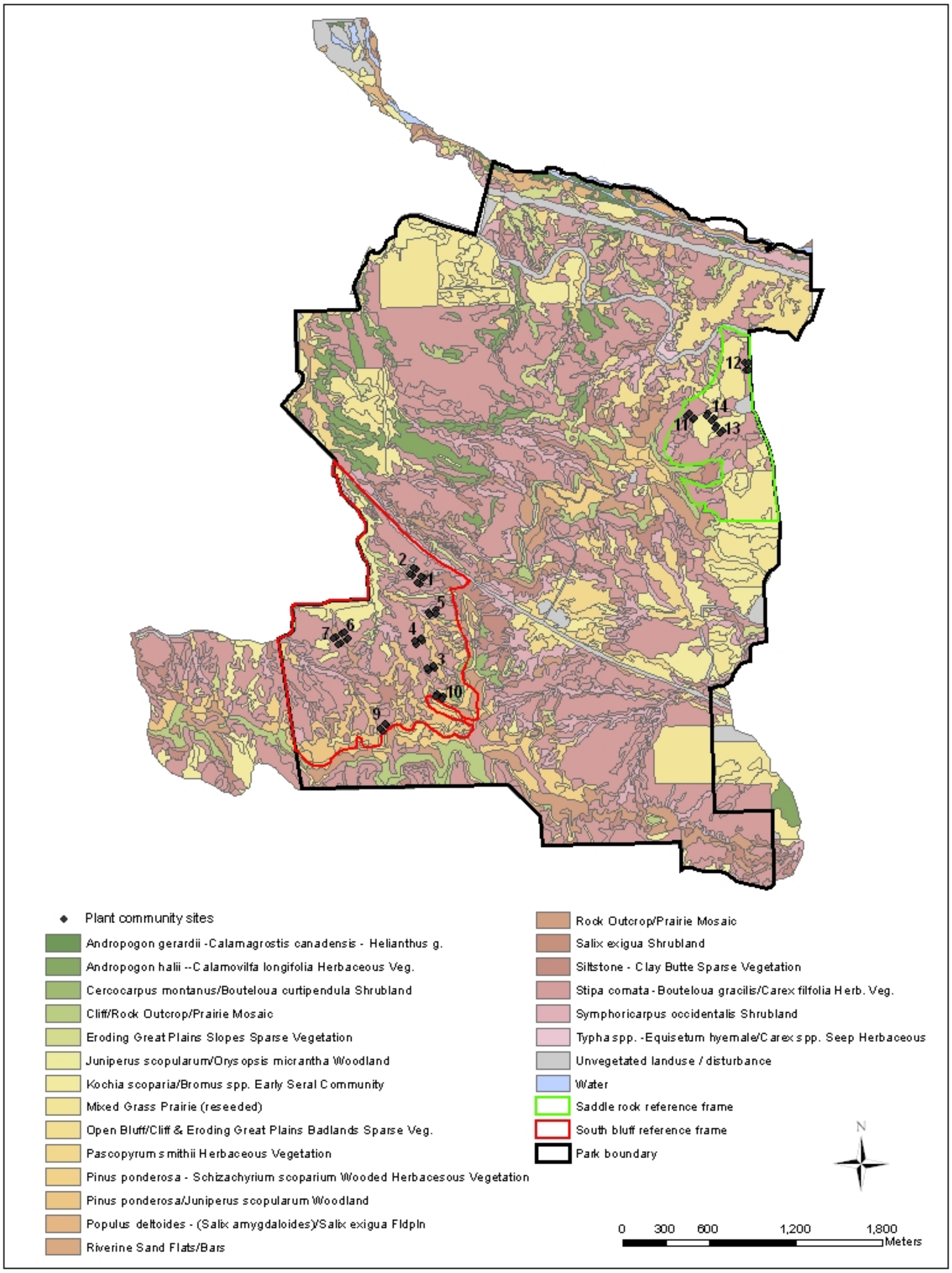


Figure 2 Scotts Bluff National Monument vegetation map and one of the selected study units. The study unit/reference frame is the South Bluff management unit. Vegetation, soils, and topography of the South Bluff unit are characteristic of the whole park.

Plant Species Richness, Diversity, and Evenness

Plant diversity for each sample unit in a study unit is calculated using the Shannon Diversity Index:

$$H' = -\sum_{i=1}^{n} p_i \ln p_i$$

where pi is the relative cover of species *i*. Species richness is determined as the total number of plant taxa recorded per sample unit. Species richness is calculated twice, once with all species included in the estimate, and again including native species only. Total species richness along with exotic species richness provides a more complete picture of the presence of both native and exotic species in the community.

Prairie Plant Guild and Exotic Species Summary

Average relative frequency and cover and associated standard deviations are also calculated for 10 plant guilds: warm-season grasses, cool-season grasses, annuals and biennials, ephemeral spring forbs, spring forbs, summer/fall forbs, legumes, ferns, and woody species (shrubs) and grass-like species. Ecological prairie plant guilds are composed of species with significant overlap in niche requirements, and that occupy similar positions along a resource gradient in a community (Root 1967, Kindscher and Wells 1995). Summary information by guilds is useful for interpreting the type and quality of prairie, as well as detecting compositional shifts among guilds that might result from management.

Exotic species form a different type of species guild, specific to species intentionally or unintentionally introduced into an area outside of its natural range. Exotic species can influence ecological processes including trophic level relationships, interspecific competition, primary and secondary succession, nutrient cycling, and ecosystem productivity, diversity, and stability (Bratton 1982). Mean exotic/native ratio, the ratio of exotic plant species to total number of native plant species, mean relative frequency and mean relative cover of exotic species are calculated for each management/study unit from sample unit estimates. Mean percent cover for exotic and native species groups is calculated slightly different than for individual species. Mean percent cover is calculated as the percent cover for a sampling unit, averaged for all plots (10), which takes into account change of frequency also.

3.0 RESULTS

<u>Agate Fossil Beds National Monument</u>

The highest number of species for both management units at AGFO occurred in 1999 and generally declined in subsequent years, with the lowest numbers of species occurring in 2004 (Table 2). Shannon diversity values remained fairly steady over the 1999-2003 period, with 1999 having the highest diversity. Diversity was lowest in 2004, especially the River Unit with a value of 1.57 (Table 3).

Both units had similar numbers of total species and numbers of exotics throughout the sample years, with the highest number of exotics occurring in 2003, and the lowest number occurring in 2004 (Table 2). Additionally, foliar cover of both natives and exotics was noticeably reduced in 2003 and 2004 from previous sample periods, though both units still had a significantly greater cover of native species than exotic species (Figure 3).

Native plant species guilds have also changed over the sample years with a shift in the major guild components. By 2003, there was a marked decrease in the relative cover of warm season grasses, as well as an increase in cool season grass relative cover (Figure 4). Most other guilds were not noticeably changed, with the exception of the grass-like species in the River Unit, which had a generally positive trend throughout the sample periods. From 2000 through 2004, needle-and-thread grass (cool season grass) and the threadleaf sedge (grass-like) decreased only about 25% in mean foliar cover. Over the same time period, the mean foliar cover of warm season grasses prairie sandreed (*Calamovilfa longifolia*) and little bluestem (*Schizachyrium scoparium*) decreased by 88% and 76% respectively.

Table 2 Agate Fossil Beds National Monument mean richness (number of species) per sample site and mean number of exotic species.

Unit	Mean richness (# exotics)				
	1998	1999	2000	2003	2004
River Unit	38 (5)	50.8 (4.5)	46.8 (4)	44.5 (5.5)	31.5 (3.5)
Carnegie Unit	40.8 (3.5)	50 (5.7)	47 (4.3)	47.5 (5.9)	35 (3.1)

Table 3 Agate Fossil Beds National Monument mean Shannon diversity and associated standard deviation.

Unit	1998	1999	2000	2003	2004
River Unit	1.92 (0.13)	2.15 (0.23)	2.0 (0.34)	2.04 (0.35)	1.57 (0.5)
Carnegie Unit	1.93 (0.47)	2.2 (0.55)	2.0 (0.57)	2.12 (0.73)	1.71 (0.94)

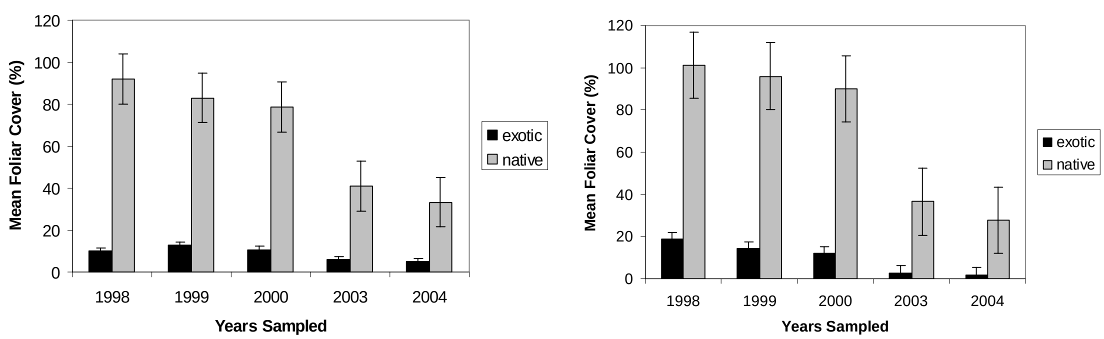


Figure 3 Agate Fossil Beds National Monument mean foliar cover of native and exotic species for Carnegie Unit (left) and the River Unit (right). Error bars are standard error. Carnegie Unit n=7, River Unit 1998 n=2, 1999-2004 n=4.

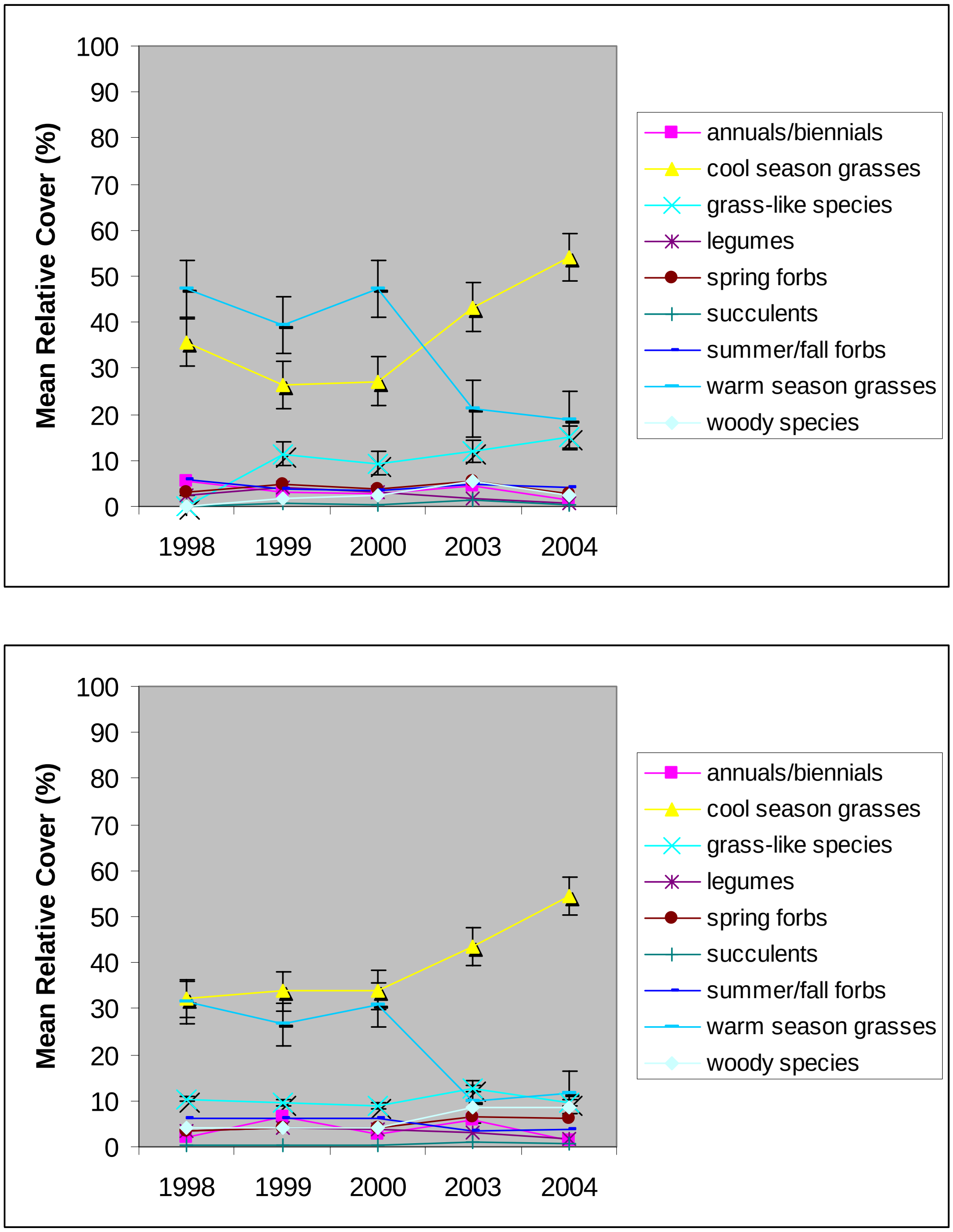


Figure 4 Agate Fossil Beds National Monument mean relative cover of guild species for the River Unit (top) and the Carnegie Unit (bottom). Error bars are standard error.

Scotts Bluff National Monument

South Bluff Unit

The total number of species on the South Bluff Unit increased for the first several years of the HTLN sample period (1997 to 1999), but decreased for the final two years (2003-2004) (Table 4). Richness was highest in 1999 and lowest in 2004, but 2003 had the greatest mean number of exotic species per site (4.57), while 1997 had the lowest with 1.86. Shannon diversity values in the South bluff unit have been declining since 1998 (Table 5). The lowest diversity of all management units and years occurred in the South bluff unit in 2004 (1.18).

While foliar cover of the South bluff sample area continues to be dominated by native species, the foliar cover of exotics has fluctuated, with the greatest foliar cover occurring during the 2003-2004 period (Figure 5). The 2003 sample period had the highest recorded cover by exotic species (23%). Foliar cover of native species was less variable, with cover declining from the highest value in 1998. The last two years of sampling (2003 & 2004) had similar values for native species cover, both much reduced from the earlier sampling periods (1997-1999).

The prescribed fire in March of 1998, coupled with above average precipitation seemed to have an invigorating effect on the dominant native species (Figure 6). The observed increase in frequency at the 1/10m plot corresponds to increased area occupied by native species and potentially accounts for the decline in annual brome following the fire. However, persistent drought conditions have decreased the dominance of native species, particularly needle and thread grass, as evidenced by a decline in frequency from its peak in 1999.

The major guilds that account for almost 100% of the vegetation cover in the South bluff unit include cool season grasses such as needle-and-thread grass and the grass-like species of the threadleaf sedge (Figure 7). Since a low in 1998 (42%), relative cover of grass-like species has been generally increasing, with the highest relative cover occurring in 2004 (59%). Almost the opposite pattern is seen with cool season grasses. In 1998, relative cover of cool season grasses and grass-like species were almost equal (42% each), since then cool season grasses have continued to decrease, with 2004 having the lowest relative cover of cool season grasses (33%). Warm season grasses are only a minor component of the flora in the South bluff unit and were seen primarily in 1997-1999, but with less than 10% relative cover.

Woodland

The woodland unit had the greatest species richness of all the management units with 46 species in 2003, however the number of exotics have also been increasing from 1997 (2.5) to 2003 (6.5) (Table 4). Additionally, the woodland unit has the highest diversity of all the units sampled, with two out of three years greater than 2.0 (Table 5). The woodlands are dominated by native species cover with exotics having less than 3% cover annually. However, native species cover has shown a general decline from 1997 to 2003 (Figure 5).

While grass-like species are still the dominant component of the woodland flora with about 40% relative cover, the remaining cover is more evenly spread over several guilds including woody species, legumes and warm season grasses, than in other management areas (Figure 7). Cool season grasses had a greater cover in 1997 than in subsequent years.

Table 4 Scotts Bluff National Monument mean richness (number of species) and the number of exotic species per site. *Asterisk indicates years not sampled.

Unit	Mean Richness (# exotics)							
	1997	1998	1999	2000	2001	2002	2003	2004
South Bluff	24.57 (1.86)	28.14 (3.14)	29.96 (2.86)	*	*	*	27.14 (4.57)	18.57 (2.43)
Woodland	39 (2.5)	*	*	33 (3)	*	*	46 (6.5)	*

Table 5 Scotts Bluff National Monument mean Shannon diversity and associated standard deviation. *Asterisk indicates years not sampled.

Unit	1997	1998	1999	2000	2001	2002	2003	2004
South Bluff Mixed Grass (n=7)	1.5 (0.31)	1.62 (0.35)	1.51 (0.28)	*	*	*	1.35 (0.34)	1.18 (0.28)
Woodlands (n=2)	2.23 (0.21)	*	*	1.98 (0.15)	*	*	2.59 (0.41)	*

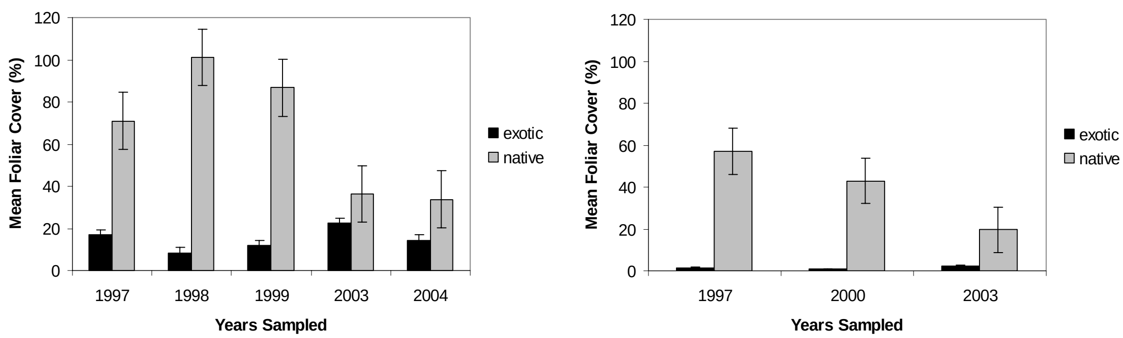


Figure 5 Scotts Bluff National Monument mean foliar cover of native and exotic species for the South Bluff Unit (left) and the Pine/Juniper Woodland (right). Error bars are standard error. South bluff n=7, Woodland n=2.

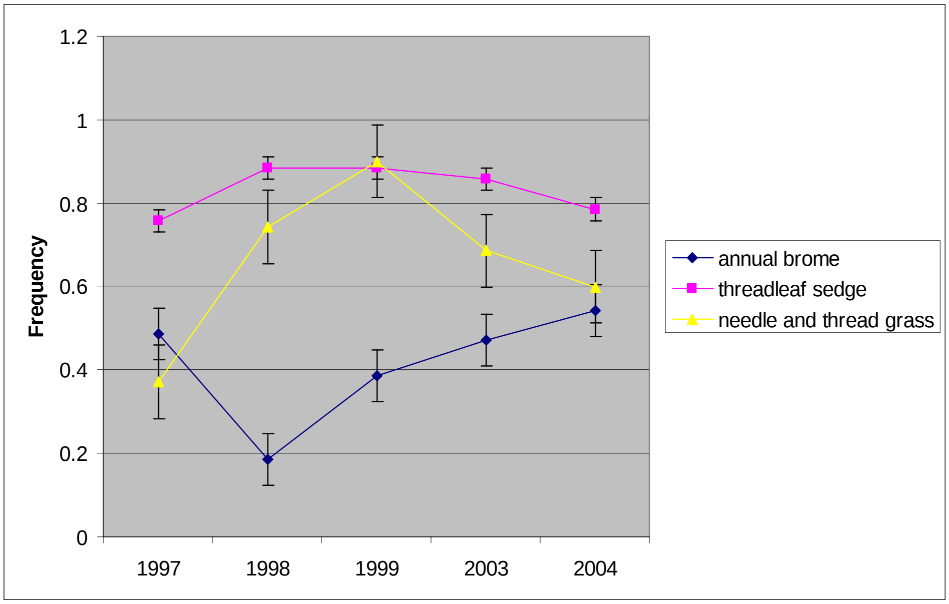
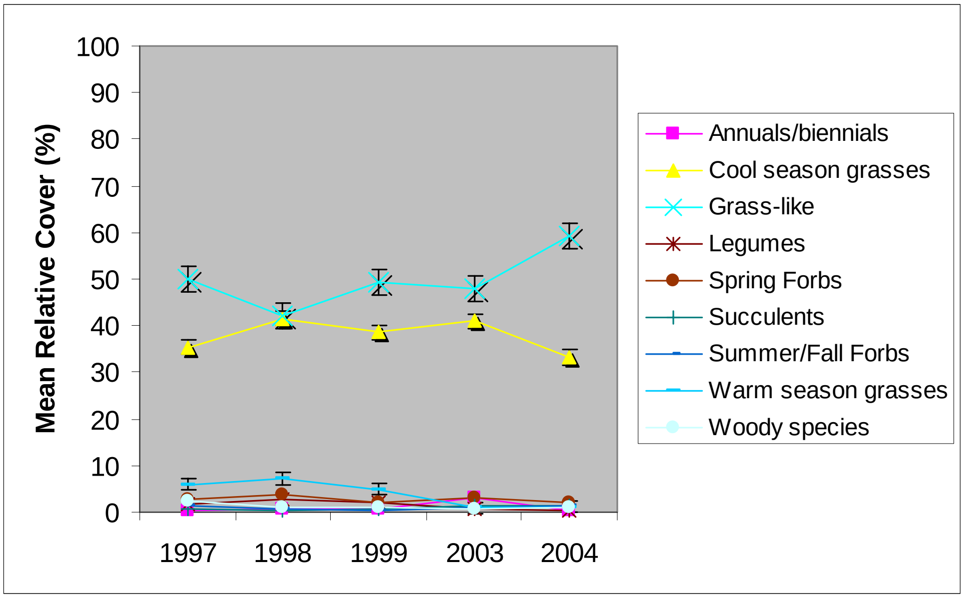


Figure 6 Frequency (measured at the 0.1m^2 scale) of three major species in the spring sample period only in the South Bluff unit before and after the 1998 prescribed fire.



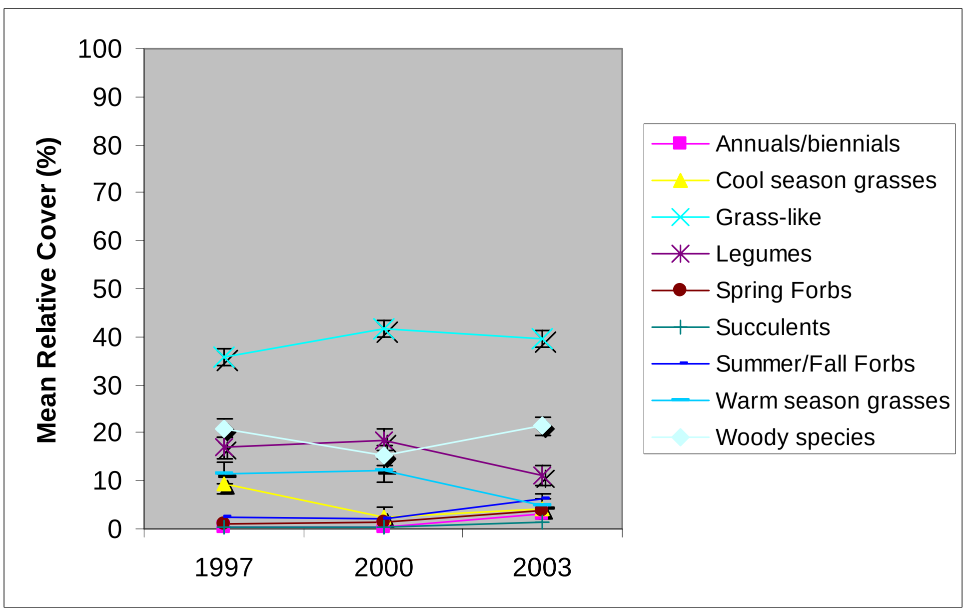


Figure 7 Scotts Bluff National Monument mean relative cover of species guilds for the South bluff Unit (top) and the Woodland Unit (bottom). Error bars are standard error.

Prairie Restoration

The restoration area has more total species than the adjacent prairie located in the nearby Saddlerock unit and than the South Bluff unit, including the greatest number of exotics (12 in 1998) (Table 6). The greatest number of species occurred in 1998, with mean number of species at 36. Diversity has been variable over the years, with highest diversity occurring in 1998 when richness was greatest, and lowest diversity occurring in 2003 (Table 7). The variation between the two restoration sample sites has been increasing with the standard deviation by 2004 almost equal to the mean Shannon diversity value. Since 2000, this unit has had greater exotic species cover than native species cover (Figure 8). This is the only unit to have greater exotic than native species cover. Native species cover has declined since 1998, when cover was almost 60%. In 2004, native species mean cover was only 8%. Exotic cover has increased from 1998 to a high in 2001 of greater than 66% cover, but has subsequently declined to 20% by 2004.

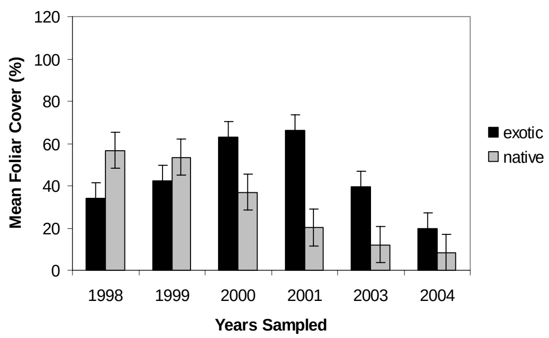
Foliar cover of native seeded grasses and forbs has been declining since 1999. By 2004, native seeded grasses comprised only 4% of the mean cover and native seeded forbs accounted for less than 1% cover (Figure 9). The restoration is composed primarily of grasses, both cool- and warm-season species, while the adjacent intact prairie in the Saddlerock unit is primarily cool season grasses and grass-like species. One dominant species of the adjacent prairie, the threadleaf sedge, is completely absent from the restoration sample sites. In the restoration unit, species of cool season grasses generally increased from 1997 to 2001 and then began a steady decline (Figure 10). A similar trend occurred in the adjacent intact prairie. In general, warm season grasses in the restoration area increased over the 1997 to 2004 period, with 2004 having the greatest relative cover (43%). Cover of warm season grasses in 2004 is almost equal to that of cool season grass cover. Over the period 2000-2004 the mean cover of the cool season grasses green needle-grass (*Stipa viridula*) and needle-and-thread grass have declined from 24.82 to 4.06%. Over the same time period, the mean foliar cover of prairie dropseed (*Sporobolus cryptandrus*), a warm season grass, has declined from 14.24 to 3.41%. Trends in these species largely explain the guild results. The dominant warm season grass prairie dropseed is known as an early invader of disturbed sites. This is in contrast to the Saddlerock unit where warm season grasses are only a minor component with less than 10% relative cover, while the threadleaf sedge is almost completely dominant.

Table 6 Scotts Bluff National Monument mean richness (number of species) and the number of exotic species per site for the restoration area and the Saddlerock unit for comparison. *Asterisk indicates years not sampled.

Unit	Mean Richness (# exotics)							
	1997	1998	1999	2000	2001	2002	2003	2004
Restoration		33.5 (7.5)	36 (12)	32 (11)	29.5 (11)	*	32 (8.5)	23 (7.5)
Saddlerock	21 (4)	15.5 (2.5)	20 (4)	*	*	*	17 (3.5)	13.5 (2)

Table 7 Scotts Bluff National Monument mean Shannon diversity and associated standard deviation for the restoration area and the Saddlerock unit for comparison. *Asterisk indicates years not sampled.

Unit	1997	1998	1999	2000	2001	2002	2003	2004
Restoration (n=2)	*	1.87 (0.35)	1.97 (0.94)	1.6 (1.07)	1.74 (1.17)	*	1.56 (1.23)	1.74 (1.71)
Saddlerock (n=2)	1.4 (0.06)	1.34 (0.11)	1.4 (0.02)	*	*	*	1.37 (0.3)	1.29 (0.27)



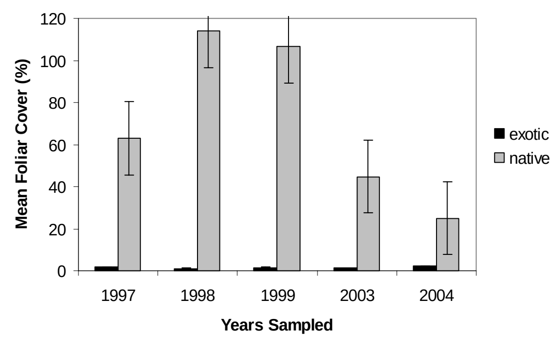


Figure 8 Scotts Bluff National Monument mean foliar cover of native and exotic species for the restoration area (left) and adjacent intact prairie located in the Saddlerock Unit (right). Restoration n=2, Saddlerock n=2.

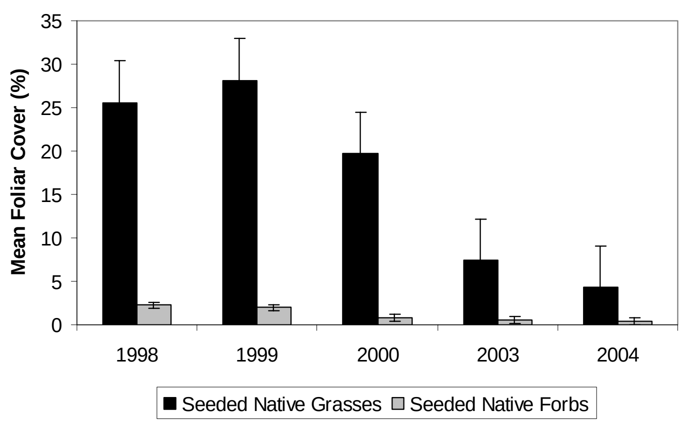
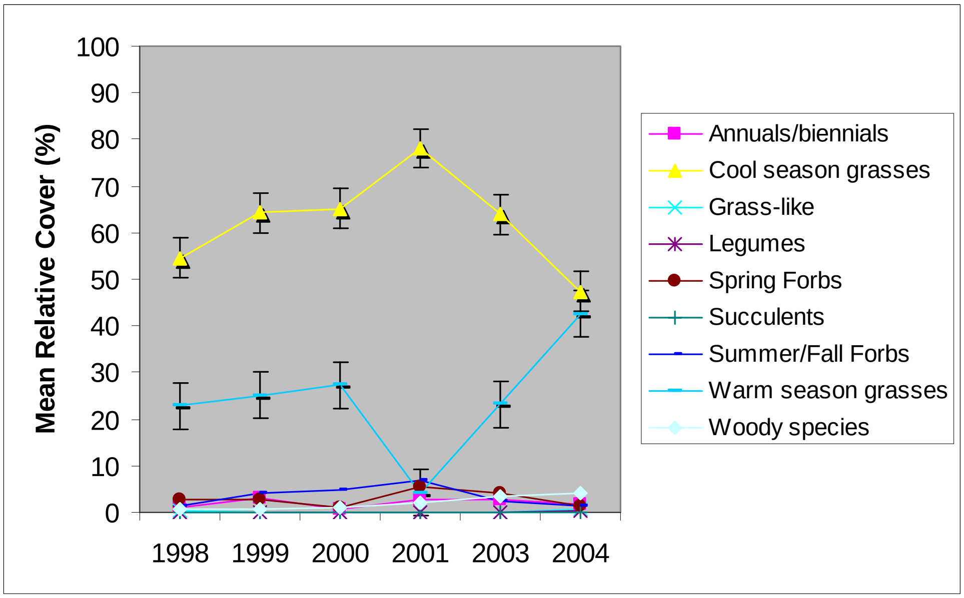


Figure 9 Scotts Bluff National Monument Restoration Area seed mix establishment and survival. Error bars show standard error.



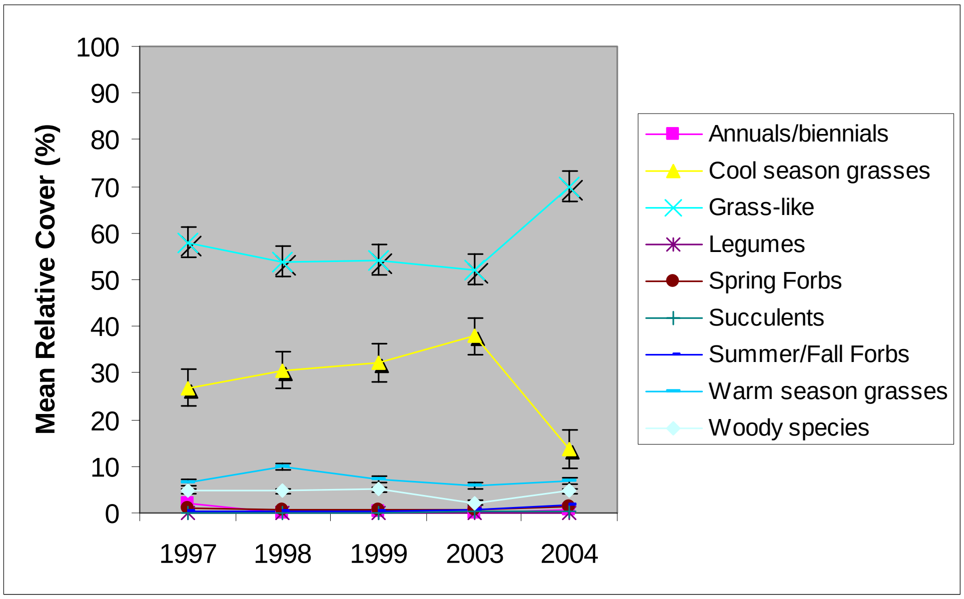


Figure 10 Scotts Bluff National Monument mean relative cover of species guilds for the Restoration area (top) and the adjacent intact prairie located in the Saddlerock Unit (bottom). Error bars are standard error.

4.0 DISCUSSION

Historically, native prairie was characterized by heterogeneity, with the interaction of fire, grazing and climate influencing vegetation community dynamics. This interplay of ecosystem drivers determined the spatial patterns, variation, dynamics, and structure of plant populations across the prairie. Today, only remnants of historic prairie remain, often with highly altered disturbance regimes due to fire suppression and overgrazing by cattle.

Mixed grass prairie at SCBL and AGFO has been virtually ungrazed since National Park Service ownership and while fire is used in a limited amount at SCBL, it is not currently part of the management regime at AGFO. Without fire and grazing many of the changes we see in the vegetation at AGFO and SCBL may be attributed to climatic variables. In 2004, HTLN staff collaborated with Dr. Amy Symstad (USGS, Northern Prairie Wildlife Research Center) to investigate the differences between grazed and ungrazed prairie. Data collected by the HTLN at SCBL was compared to data collected outside the monument in grazed prairies. Dr. Symstad's preliminary results suggest few differences between grazed and ungrazed sites except for the greater presence of grama grass in the grazed sites. Dr. Symstad's report is available at: http://www1.nature.nps.gov/im/units/ngpn/Pages/monitoring.htm

Grassland vegetation developed under a great diversity of climatic conditions (Albertson *et al.* 1957), with drought a common occurrence on prairies in the Great Plains. Plant species are adapted to extremes in both temperature and precipitation that are part of the prairie environment. Over short terms (100 years or less), shifts in prairie composition have been documented to be associated with changed precipitation (Weaver 1954). During wet years prairie plants flourish in both foliar cover and density, but during dry years much of the gains seen in wet years are lost. While most prairie plant species can rebound after drought, extreme droughts can shift species composition largely due to species different water-use capabilities (Albertson *et al.* 1957).

The Heartland I&M and Prairie Cluster Prototype Monitoring Program (formerly the Prairie Cluster Prototype Long-Term Ecological Monitoring Program) has been monitoring at SCBL and AGFO since 1997. During that time, a multiple year drought has occurred in western Nebraska. Plant communities have been affected in general, with both SCBL and AGFO having a widespread decrease in both the number of species and the foliar cover of species. Management units across both parks have seen a 50-70% reduction in total foliar cover at each sample site compared to earlier non-drought years (Tables 8-10). Native species dominate the community composition in all management units except the SCBL restoration area; however, the average number of species found per sample site has declined by nearly 35% since 1999. With reduced plant cover, most management units have increased amounts of bare ground in the sample site.

Precipitation at SCBL has been below average for the last five years (Figure 11), while precipitation at AGFO has been below average for the last three out of four years (Figure 12). In 2003, AGFO had three large rain events of greater than one inch rain in a single day occurring May 8, August 8 and Sept. 9. Overall, this doesn't appear to have had a significant effect on the vegetation, though there is increased diversity for that year. The multiple-year drought, seen in 2001, 2002 and 2004 seem to be the overriding factor with both number and cover of species declining. Also worthy of note is the change in HTLN sampling intensity that occurred in the 2004 field season. From 1997 to 2003, the

HTLN sampled twice per year with sampling occurring in June and July. In 2004, the decision was made to switch to a single sample occurring in late June. It is possible that the low numbers of species in 2004 may be due to the change in sampling intensity, though 2003 had similar results.

Interestingly, with the multiple-year drought occurring at both AGFO and SCBL, plant community dynamics, presumably in response to decreased precipitation, are very different between the two parks. While located near each other geographically, SCBL and AGFO contain different vegetation communities. At AGFO, HTLN sample sites are primarily composed of three plant community types, prairie sandreed – sand bluestem, needle-and-thread grass – blue grama – threadleaf sedge, and little bluestem – blue grama – threadleaf sedge (Figure 13). At SCBL, HTLN mixed-grass prairie sample sites are composed primarily of the needle-and-thread grass – blue grama – threadleaf sedge community (Figure 14). SCBL sample areas also include a Ponderosa pine woodland and a restoration area.

While many plant species are common to both parks, they have responded differently to the drought within each park. The difference in composition of community types may account for the different response to drought conditions. For instance, at AGFO, where there is a greater warm season grass component than SCBL, needle-and-thread grass (cool season grass) and the threadleaf sedge (grass-like) decreased only about 25% in mean foliar cover. Over the same time period, the mean foliar cover of warm season grasses prairie sandreed and little bluestem decreased by 88% and 76% respectively. This is seen in both management units at AGFO. However, at SCBL, in the South Bluff unit, which has a very small warm-season grass component, needle-and-thread grass decreased 71% over the 1998 to 2004 period, while the threadleaf sedge decreased only 51% and actually increased mean foliar cover from 2003 to 2004. The threadleaf sedge does not appear to be as affected by the drought as the grass species present.

Management of SCBL during the 1997 to 2004 period of HTLN monitoring has included two prescribed burn events. The first prescribed burn in over 50 years occurred in the SCBL South Bluff unit in 1998. It appears that the prescribed fire in 1998, in conjunction with above-average precipitation for that year, resulted in a short-term decrease in annual exotic brome grass coupled with an increase in total foliar cover and species richness. However, these trends seem to be overwhelmed by the effects of the drought in later years. Persistent drought conditions have decreased the dominance of native species, particularly needle-and-thread grass (*Stipa comata*), which has declined in frequency by nearly 20% since 1999. The declining abundance of native species may be favoring the establishment of exotic brome grass which has increased in frequency by 30% over the same period.

Management efforts in the restoration area at SCBL were initially successful in establishing native species. The foliar cover of seeded grass species was estimated at 25 – 30% in 1998 and 1999. In subsequent years the unit has become increasingly dominated by exotic species whose foliar cover was estimated at 20% in 2004. The foliar cover of seeded grasses was approximately 7% in 2004. One dominant species of the adjacent prairie, the threadleaf sedge (*Carex filifolia*), is completely absent from the restoration sample sites. The restoration unit was treated in May of 2002 with prescribed fire with little noticeable effect. Sustained effort may be required to move the restoration towards a model species composition and structure.

The Pondera Pine/ Juniper Woodlands at SCBL are one of the few communities to have increased richness and diversity by 2003. As would be expected, the guild structure is very different than the grassland areas. Grass-like species are still the dominant component, but additional guilds such as woody species, legumes, and warm-season grasses comprise a significant portion of the community. This difference in composition may account for the different response to drought conditions. Tree species have remained virtually unchanged from 1997 to 2003, with little difference in all vertical layers from the number of seedlings regenerating to overstory species diameter and density from 1997 to 2003.

Through plant community monitoring at SCBL and AGFO since 1997, the HTLN have been able to document plant community dynamics in relation to climatological trends. While sample sites have not been extensive throughout the park, data collected is a valuable resource to establish a baseline for comparison with future changes.

Table 8 Agate Fossil Beds National Monument mean total foliar cover (%) for all species including exotic species.

Unit	1998	1999	2000	2003	2004
Carnegie	101.99	95.65	89.29	46.69	38.2
River	119.9	110.4	102.09	39.41	29.83

Table 9 Scott's Bluff National Monument mean total foliar cover (%) for all species including exotic species for South Bluff Unit, including the woodland area.

Unit	1997	1998	1999	2000	2003	2004
Southbluff	87.87	109.54	98.54	*	58.99	48.23
Woodland	58.6	*	*	43.65	21.8	*

Table 10 Scott's Bluff National Monument mean total foliar cover (%) for all species including exotic species for the restoration area and the adjacent intact prairie.

Unit	1997	1998	1999	2000	2003	2004
Restoration	*	90.9	95.9	99.75	51.75	27.975
Saddlerock Unit	64.8	114.9	108	*	46.025	27.025

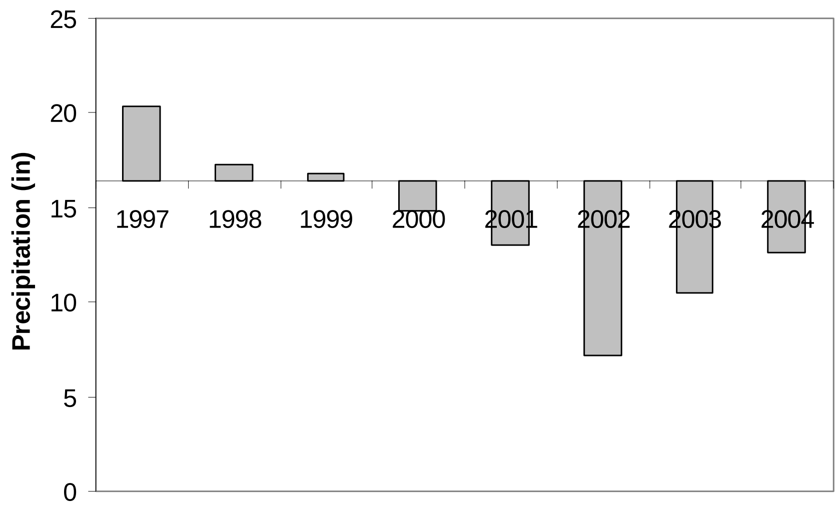


Figure 11 Precipitation at Scotts Bluff National Monument, with a 30 year average of 16.399 inches.

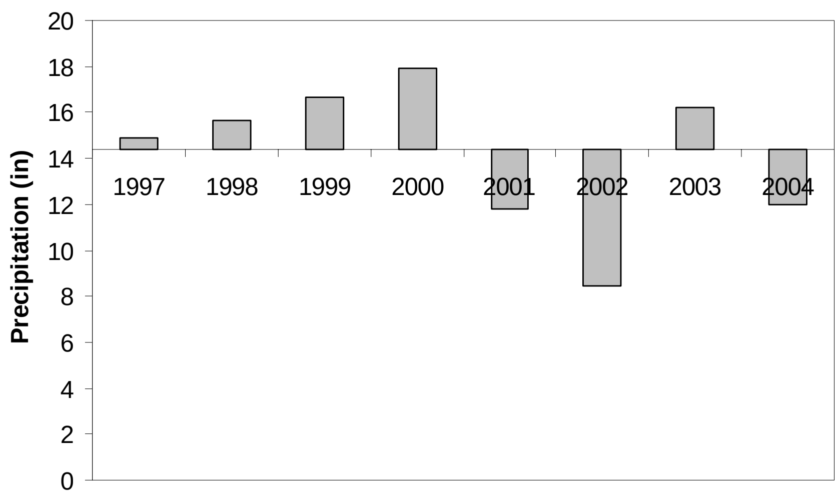


Figure 12 Precipitation at Agate Fossil Beds National Monument, with a 30 year average of 14.357 inches.

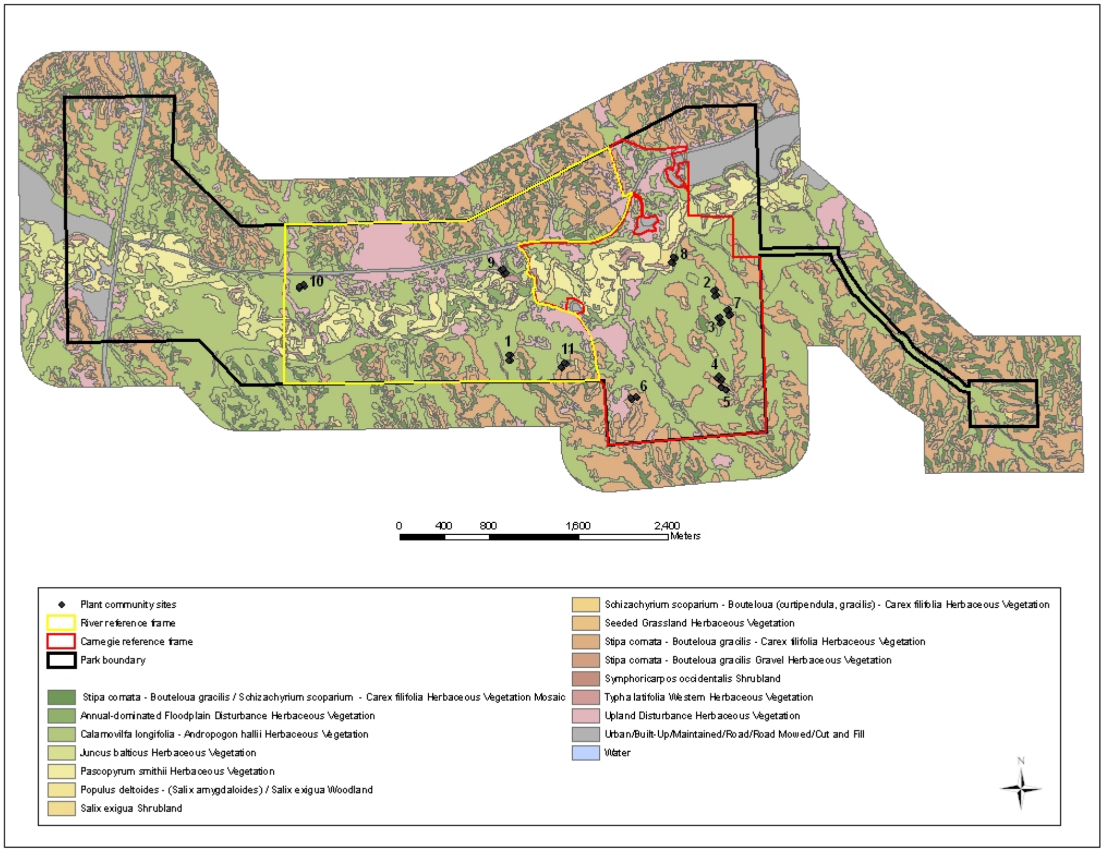


Figure 13 Agate Fossil Beds National Monument with vegetation map and the selected study units with numbered HTLN vegetation monitoring sample sites.

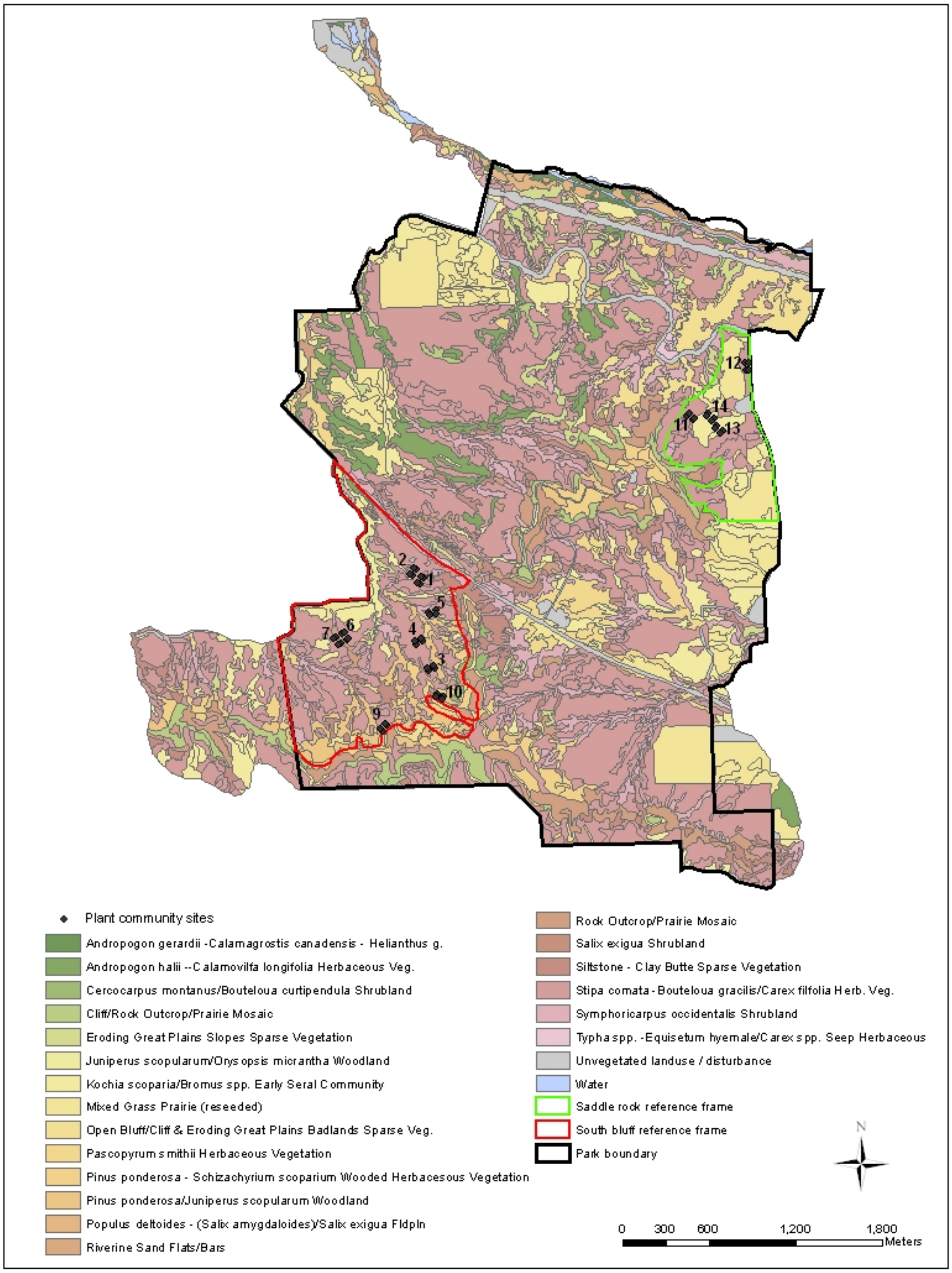


Figure 14 Scotts Bluff National Monument with vegetation map and selected study sites with numbered HTLN vegetation monitoring sites.

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APPENDIX A. Top Ten species for each management unit at AGFO and SCBL for two years.

AGFO Carnegie Unit 1998 Plant Community Composition: Herbaceous and Shrub Species.

Species	Common Name	Frequency	Mean Cover	Importance Value
STIPA COMATA	Needle-and-thread grass	82.86%	27.20	0.1362
CALAMOVILFA LONGIFOLIA	Sand-reed	58.57%	21.28	0.0809
CAREX FILIFOLIA	Threadleaf Sedge	34.29%	34.90	0.0634
SCHIZACHYRIUM SCOPARIUM	Little bluestem	28.57%	27.95	0.0543
BOUTELOUA GRACILIS	Blue grama	65.71%	8.85	0.0501
POA PRATENSIS	Kentucky bluegrass	18.57%	45.58	0.0451
PASCOPYRUM SMITHII	Western wheatgrass	15.71%	29.41	0.0270
YUCCA GLAUCA	Soap plant	40.00%	7.50	0.0270
GUTIERREZIA SAROTHRAE	Matchbrush	31.43%	8.25	0.0249
EQUISETUM LAEVIGATUM	Smooth scouring rushes	14.29%	23.85	0.0216

AGFO Carnegie Unit 2004 Plant Community Composition: Herbaceous and Shrub Species.

Species	Common Name	Frequency	Mean Cover	Importance Value
STIPA COMATA	Needle-and-thread grass	85.71%	17.94	0.2350
POA PRATENSIS	Kentucky bluegrass	21.43%	21.33	0.0685
CAREX FILIFOLIA	Threadleaf Sedge	31.43%	16.52	0.0612
YUCCA GLAUCA	Soap plant	48.57%	4.65	0.0481
CALAMOVILFA LONGIFOLIA	Sand-reed	60.00%	2.13	0.0454
PASCOPYRUM SMITHII	Western wheatgrass	40.00%	3.96	0.0422
BOUTELOUA GRACILIS	Blue grama	60.00%	0.80	0.0336
VULPIA OCTOFLORA	Six-weeks fescue	58.57%	0.62	0.0326
SCHIZACHYRIUM SCOPARIUM	Little bluestem	27.14%	4.87	0.0294
LYGODESMIA JUNCEA	Skeleton-weed	47.14%	0.50	0.0259

AGFO River Unit 1998 Plant Community Composition: Herbaceous and Shrub Species.

Species	Common Name	Frequency	Mean Cover	Importance Value
CALAMOVILFA LONGIFOLIA	Sand-reed	95.00%	40.53	0.1965
STIPA COMATA	Needle-and-thread grass	100.00%	31.40	0.1756
BOUTELOUA GRACILIS	Blue grama	100.00%	9.33	0.0774
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	50.00%	30.35	0.0747
PASCOPYRUM SMITHII	Western wheatgrass	55.00%	6.77	0.0342
ARTEMISIA FRIGIDA	Prairie-sagewort	40.00%	11.19	0.0338
TRADESCANTIA OCCIDENTALIS	Prairie spiderwort	65.00%	1.81	0.0305
HELIANTHUS PETIOLARIS	Plains sunflower	45.00%	6.50	0.0303
LACTUCA SERRIOLA	Prickly lettuce	45.00%	4.89	0.0277
CHENOPODIUM PRATERICOLA	Narrow-leaf goosefoot	55.00%	0.50	0.0226

AGFO River Unit 2004 Plant Community Composition: Herbaceous and Shrub Species.

Species	Common Name	Frequency	Mean Cover	Importance Value
STIPA COMATA	Needle-and-thread grass	100.00%	13.23	0.2858
CAREX FILIFOLIA	Threadleaf Sedge	22.50%	23.67	0.0794

BOUTELOUA GRACILIS	Blue grama	97.50%	1.82	0.0787
CALAMOVILFA LONGIFOLIA	Sand-reed	85.00%	1.51	0.0627
LYGODESMIA JUNCEA	Skeleton-weed	80.00%	0.50	0.0469
ANDROPOGON HALLII	Sand bluestem	25.00%	7.30	0.0405
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	25.00%	3.90	0.0329
PASCOPYRUM SMITHII	Western wheatgrass	40.00%	0.81	0.0268
ERIOGONUM ANNUUM	Annual eriogonum	37.50%	0.50	0.0214
VULPIA OCTOFLORA	Six-weeks fescue	37.50%	0.50	0.0200

SCBL South bluff Unit 1998 Plant Community Composition: Herbaceous and Shrub Species.

Species	**Common Name**	**Frequency**	**Mean Cover**	**Importance Value**
CAREX FILIFOLIA	Threadleaf Sedge	100.00%	42.67	0.2486
STIPA COMATA	Needle-and-thread grass	100.00%	32.79	0.2002
PASCOPYRUM SMITHII	Western wheatgrass	72.86%	11.58	0.0793
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	40.00%	20.59	0.0628
SPHAERALCEA COCCINEA	Scarlet mallow	72.86%	3.09	0.0517
BOUTELOUA GRACILIS	Blue grama	67.14%	3.05	0.0472
GAURA COCCINEA	Scarlet gaura	57.14%	1.73	0.0348
CHENOPODIUM PRATERICOLA	Narrow-leaf goosefoot	42.86%	1.23	0.0260
BOUTELOUA CURTIPENDULA	Side-oats grama-grass	17.14%	16.42	0.0209
LYGODESMIA JUNCEA	Skeleton-weed	34.29%	0.71	0.0203

SCBL South bluff Unit 2004 Plant Community Composition: Herbaceous and Shrub Species.

Species	**Common Name**	**Frequency**	**Mean Cover**	**Importance Value**
CAREX FILIFOLIA	Threadleaf Sedge	95.71%	21.10	0.2769
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	67.14%	21.41	0.2045
STIPA COMATA	Needle-and-thread grass	98.57%	9.37	0.1704
PASCOPYRUM SMITHII	Western wheatgrass	77.14%	1.81	0.0760
SPHAERALCEA COCCINEA	Scarlet mallow	65.71%	0.72	0.0571
BOUTELOUA GRACILIS	Blue grama	34.29%	0.71	0.0290
VULPIA OCTOFLORA	Six-weeks fescue	32.86%	0.50	0.0281
LYGODESMIA JUNCEA	Skeleton-weed	27.14%	0.50	0.0233
CAREX SPP	Sedge spp	2.86%	19.00	0.0111
GAURA COCCINEA	Scarlet gaura	14.29%	0.50	0.0104

SCBL Restoration Area 1998 Plant Community Composition: Herbaceous and Shrub Species.

Species	**Common Name**	**Frequency**	**Mean Cover**	**Importance Value**
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	50.00%	39.30	0.1411
PASCOPYRUM SMITHII	Western wheatgrass	85.00%	16.15	0.1170
SPOROBOLUS CRYPTANDRUS	Sand dropseed	75.00%	18.17	0.1004
VERBENA BRACTEATA	Prostrate vervain	75.00%	16.23	0.0927
MELILOTUS OFFICINALIS	Yellow sweet clover	45.00%	20.11	0.0616
STIPA COMATA	Needle-and-thread grass	60.00%	9.79	0.0529
STIPA VIRIDULA	Green needle-grass	50.00%	6.90	0.0433
BROMUS INERMIS	Smooth brome	55.00%	5.36	0.0414
BUCHLOE DACTYLOIDES	Buffalograss	85.00%	1.24	0.0404
BOUTELOUA GRACILIS	Blue grama	65.00%	1.27	0.0284

SCBL Restoration Area 2004 Plant Community Composition: Herbaceous and Shrub Species.

Species	Common Name	Frequency	Mean Cover	Importance Value
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	100.00%	16.18	0.3147
SPOROBOLUS CRYPTANDRUS	Sand dropseed	80.00%	3.41	0.0979
SALSOLA SPP	Russian thistle	100.00%	1.85	0.0847
STIPA COMATA	Needle-and-thread grass	70.00%	3.14	0.0834
PASCOPYRUM SMITHII	Western wheatgrass	95.00%	0.89	0.0702
STIPA VIRIDULA	Green needle-grass	60.00%	0.92	0.0444
KOCHIA SCOPARIA	Summer-cypress	60.00%	0.50	0.0419
BROMUS INERMIS	Smooth brome	55.00%	0.95	0.0405
BOUTELOUA CURTIPENDULA	Side-oats grama-grass	30.00%	1.33	0.0227
BOUTELOUA GRACILIS	Blue grama	35.00%	0.50	0.0195

SCBL Saddlerock Unit 1998 Plant Community Composition: Herbaceous and Shrub Species.

Species	Common Name	Frequency	Mean Cover	Importance Value
CAREX FILIFOLIA	Threadleaf Sedge	100.00%	61.25	0.3477
STIPA COMATA	Needle-and-thread grass	100.00%	25.13	0.1900
BOUTELOUA GRACILIS	Blue grama	95.00%	11.55	0.1251
PASCOPYRUM SMITHII	Western wheatgrass	65.00%	12.23	0.0867
KRASCHENINNIKOVIA LANATA	White sage, winter fat	55.00%	10.05	0.0670
SPHAERALCEA COCCINEA	Scarlet mallow	60.00%	0.92	0.0506
ORYZOPSIS HYMENOIDES	Indian ricegrass	30.00%	5.75	0.0322
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	20.00%	1.13	0.0173
SALSOLA SPP	Russian thistle	15.00%	5.33	0.0154
LYGODESMIA JUNCEA	Skeleton-weed	10.00%	1.75	0.0090

SCBL Saddlerock Unit 2004 Plant Community Composition: Herbaceous and Shrub Species.

Species	Common Name	Frequency	Mean Cover	Importance Value
CAREX FILIFOLIA	Threadleaf Sedge	100.00%	18.15	0.4016
STIPA COMATA	Needle-and-thread grass	100.00%	2.48	0.1249
BOUTELOUA GRACILIS	Blue grama	95.00%	1.29	0.1039
KRASCHENINNIKOVIA LANATA	White sage, winter fat	55.00%	2.77	0.0648
PASCOPYRUM SMITHII	Western wheatgrass	60.00%	0.92	0.0569
SALSOLA SPP	Russian thistle	55.00%	0.73	0.0493
SPHAERALCEA COCCINEA	Scarlet mallow	50.00%	0.50	0.0431
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	20.00%	8.38	0.0406
CHENOPODIUM PRATERICOLA	Narrow-leaf goosefoot	35.00%	0.50	0.0301
LYGODESMIA JUNCEA	Skeleton-weed	30.00%	0.92	0.0292

SCBL Woodland Unit 1997 Plant Community Composition: Herbaceous and Shrub Species.

Species	Common Name	Frequency	Mean Cover	Importance Value
CAREX FILIFOLIA	Threadleaf Sedge	90.00%	21.97	0.2032
THERMOPSIS RHOMBIFOLIA	Buckbean	70.00%	13.07	0.0921
CERCOCARPUS MONTANUS	Mountain mahogany	80.00%	7.09	0.0747
STIPA COMATA	Needle-and-thread grass	75.00%	5.07	0.0603
BOUTELOUA CURTIPENDULA	Side-oats grama-grass	85.00%	3.38	0.0557
SCHIZACHYRIUM SCOPARIUM	Little bluestem	75.00%	4.73	0.0516

YUCCA GLAUCA	Soap plant	80.00%	3.72	0.0514
RHUS TRILOBATA	Squaw-bush	75.00%	3.63	0.0442
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	90.00%	1.06	0.0375
KOELERIA MACRANTHA	Junegrass	85.00%	1.38	0.0362

SCBL Woodland Unit 2003 Plant Community Composition: Herbaceous and Shrub Species.

Species	**Common Name**	**Frequency**	**Mean Cover**	**Importance Value**
CAREX FILIFOLIA	Threadleaf Sedge	65.00%	12.54	0.1997
ANNUAL BROMUS SPP	B. tectorum, B. japonicus	95.00%	1.55	0.0652
YUCCA GLAUCA	Soap plant	65.00%	2.38	0.0596
THERMOPSIS RHOMBIFOLIA	Buckbean	65.00%	1.85	0.0528
CERCOCARPUS MONTANUS	Mountain mahogany	50.00%	3.20	0.0522
ELYMUS TRACHYCAULUS	slender wheatgrass	95.00%	0.76	0.0495
RHUS TRILOBATA	Squaw-bush	80.00%	0.97	0.0455
BOUTELOUA CURTIPENDULA	Side-oats grama-grass	60.00%	1.33	0.0362
VICIA AMERICANA	American vetch	80.00%	0.50	0.0360
DESCURAINIA PINNATA	Tansy-mustard	75.00%	0.50	0.0332